# Hepatoprotective effects of systemic ER activation

BulkRNAseq - Pathway analysis

Christian Sommerauer & Carlos Gallardo

11 August, 2022

```
# source and library import
source('code/00_helper_functions.R')
library(tidyverse)
library(fgsea)
```

```
# color palettes
colPals <- list()
colPals$conditions <- setNames(c('#E98BB6', '#B02262', '#7F9AD7', '#2A2F72', '#7DC7D1', '#339ACD', '#35
                               c('CDf', 'HFDf', 'CDm', 'HFDm', 'DPN', 'DIP', 'E2', 'PPT'))
colPals$RdBu <- rev(RColorBrewer::brewer.pal(n=11, name = 'RdBu'))
colPals$UpDown <- setNames(colPals$RdBu[c(10,2)],
                           c('up', 'down'))
colPals$clusters <- setNames(c('#A9D265', '#82506D', '#FA9F1C', '#676A6E'),
                             c('1', '2', '3', '4'))
```

## Load data

```
# consensus differentially expressed genes
DEGs <- readRDS('results/bulkRNAseq_mmus_DEGs.rds')

# treatment response sets
DEG_sets <- readRDS('results/bulkRNAseq_mmus_DEG_sets.rds')

# RNAseq data
RNAseq <- readRDS('results/bulkRNAseq_mmus_data_filt_norm.rds')

# mmus reactome gene sets from Zhang et al 2020
gene_sets <- list()
gene_sets$reactome <- readGMT('data/reactome_mmus_Zhang2020_annotation.gmt')
```

## Gene set enrichment analysis (GSEA)

```
# rank genes by signed -log10 P value
gsea_genes_rnk <- lapply(DEGs$unfilt[c('CDmVsHFDm','DPNVsHFDm','DIPVsHFDm','E2VsHFDm','PPTVsHFDm')], fu
  x %>%
    dplyr::mutate(neg_log10Pval = -log10(pvalue)*sign(log2FoldChange)) %>%
    dplyr::mutate(neg_log10Pval = ifelse(is.na(neg_log10Pval), 0, neg_log10Pval)) %>%
    dplyr::arrange(dplyr::desc(neg_log10Pval))
})
```

```
# run GSEA
gsea_res <- lapply(gsea_genes_rnk, function(x) {
  runGSEA(gene.rnk = setNames(x$neg_log10Pval,
                              x$external_gene_name),
          gene.sets = gene_sets$reactome$genesets,
          min.size = 10,
          max.size = 500,
          nproc = 3)
})
```

## Build network of perturbed pathways

```
# generate node and edge tables
gsea_net <- buildGSEANetwork(gsea_res, gene_sets$reactome$genesets)

# export node and edge tables for Cytoscape input
# filter for nodes connected by at least 1 edge
nodes <- gsea_net$nodes %>%
  dplyr::filter(id %in% c(gsea_net$edges$source, gsea_net$edges$target))

# write.table(nodes,
#             file = 'results/bulkRNAseq_mmus_GSEA_reactome_network_nodes.tsv',
#             sep = '\t',
#             col.names = TRUE,
#             row.names = FALSE,
#             quote = FALSE)
#
# write.table(gsea_net$edges,
#             file = 'results/bulkRNAseq_mmus_GSEA_reactome_network_edges.tsv',
#             sep = '\t',
#             col.names = TRUE,
#             row.names = FALSE,
#             quote = FALSE)
```

## Collapse network to pathway clusters

```
# load cluster assignments from Cytoscape
gsea_net_clusters <- read.table(
  file = 'results/bulkRNAseq_mmus_GSEA_reactome_network_clusters.tsv',
  stringsAsFactors = FALSE,
  sep = '\t',
  header = TRUE,
  quote = '')

# generate reduced network
# collapse clusters and correlate according to NES profiles
gsea_net_reduced <- list()

gsea_net_reduced$nodes <- gsea_net_clusters %>%
  dplyr::inner_join(nodes, by = 'id') %>%
  dplyr::group_by(cl_label) %>%
```

```
  dplyr::summarise(cluster = glayCluster,
                   id = cl_label,
                   n = dplyr::n(),
                   CDmVsHFDm_NES = mean(CDmVsHFDm_NES),
                   DPNVsHFDm_NES = mean(DPNVsHFDm_NES),
                   DIPVsHFDm_NES = mean(DIPVsHFDm_NES),
                   E2VsHFDm_NES = mean(E2VsHFDm_NES),
                   PPTVsHFDm_NES = mean(PPTVsHFDm_NES),
                   genes = paste(genes, collapse = ',')) %>%
  unique() %>%
  dplyr::mutate(genes = paste(unique(unlist(strsplit(genes, ','))), collapse = ',')) %>%
  dplyr::mutate(size = length(unlist(strsplit(genes, ',')))) %>%
  dplyr::ungroup(cl_label) %>%
  dplyr::select(-cl_label) %>%
  dplyr::arrange(cluster)


comb <- expand.grid(gsea_net_reduced$nodes$id, gsea_net_reduced$nodes$id)
comb <- split(comb, 1:nrow(comb))

gsea_net_reduced$edges <- lapply(comb, function(x) {
  names.NES <- colnames(gsea_net_reduced$nodes)[grep('NES', colnames(gsea_net_reduced$nodes))]
  scores.x <- unlist(gsea_net_reduced$nodes[gsea_net_reduced$nodes$id == x[[1]], names.NES])
  scores.y <- unlist(gsea_net_reduced$nodes[gsea_net_reduced$nodes$id == x[[2]], names.NES])
  cor.res <- cor.test(scores.x, scores.y)

  genes.x <- unlist(strsplit(unlist(gsea_net_reduced$nodes[gsea_net_reduced$nodes$id == x[[1]], 'genes'
  genes.y <- unlist(strsplit(unlist(gsea_net_reduced$nodes[gsea_net_reduced$nodes$id == x[[2]], 'genes'

  data.frame(source = x[[1]],
             target = x[[2]],
             interaction = 'correlation',
             correlation = cor.res$estimate,
             pval = cor.res$p.value,
             sign = ifelse(cor.res$estimate>0, 'POS', 'NEG'),
             weight = abs(cor.res$estimate),
             genes = paste(dplyr::intersect(genes.x, genes.y), collapse = ','),
             size = length(dplyr::intersect(genes.x, genes.y)))
}) %>%
  dplyr::bind_rows() %>%
  dplyr::filter(!duplicated(select(., -c('source', 'target', 'genes')))) %>%
  dplyr::filter(source != target & weight>0.9) # filter edges to cor >0.9 or <-0.9

# write.table(gsea_net_reduced$nodes,
#             file = 'results/bulkRNAseq_mmus_GSEA_reactome_network_reduced_nodes.tsv',
#             sep = '\t',
#             col.names = TRUE,
#             row.names = FALSE,
#             quote = FALSE)
#
# write.table(gsea_net_reduced$edges,
#             file = 'results/bulkRNAseq_mmus_GSEA_reactome_network_reduced_edges.tsv',
#             sep = '\t',
```

```
#             col.names = TRUE,
#             row.names = FALSE,
#             quote = FALSE)
```

## Define gene sets for reactome pathway clusters

```
# list of pathway cluster gene sets
pathway_sets <- lapply(setNames(gsea_net_reduced$nodes$id, gsea_net_reduced$nodes$id), function(x) {
  gsea_net_reduced$nodes %>%
    dplyr::filter(id == x) %>%
    dplyr::pull(genes) %>%
    strsplit(',') %>%
    unlist()
})

# check distribution of treatment response sets
DEGs_pathway_distr <- lapply(seq(1:length(pathway_sets)), function(i) {
  data.frame(id = i,
             cluster = names(pathway_sets)[i],
             total_genes = length(pathway_sets[[i]]),
             total_genes_in_background = length(dplyr::intersect(pathway_sets[[i]], RNAseq$annotation$e
             non_reverted = length(dplyr::intersect(pathway_sets[[i]], DEG_sets$gene_symbols$non_revert
             reverted = length(dplyr::intersect(pathway_sets[[i]], DEG_sets$gene_symbols$reverted)),
             DPN_DIP = length(dplyr::intersect(pathway_sets[[i]], DEG_sets$gene_symbols$DPN_DIP)),
             E2_PPT = length(dplyr::intersect(pathway_sets[[i]], DEG_sets$gene_symbols$E2_PPT)))
}) %>%
  dplyr::bind_rows()

# write.table(DEGs_pathway_distr,
#             file = 'results/bulkRNAseq_mmus_GSEA_reactome_clusters_DEGs_intersection.tsv',
#             sep = '\t',
#             col.names = TRUE,
#             row.names = FALSE,
#             quote = FALSE)
```

## Export data

```
# GSEA results and network
# saveRDS(gsea_res, file = 'results/bulkRNAseq_mmus_GSEA_reactome_results.rds')
# saveRDS(gsea_net, file = 'results/bulkRNAseq_mmus_GSEA_reactome_network.rds')

# gene sets for defined reactome pathway clusters
# saveRDS(pathway_sets, file = 'results/bulkRNAseq_mmus_GSEA_reactome_cluster_sets.rds')
```

```
sessionInfo()
```

```
## R version 4.0.5 (2021-03-31)
## Platform: x86_64-w64-mingw32/x64 (64-bit)
## Running under: Windows 10 x64 (build 19044)
##
## Matrix products: default
##
```

```
## locale:
## [1] LC_COLLATE=English_United States.1252
## [2] LC_CTYPE=English_United States.1252
## [3] LC_MONETARY=English_United States.1252
## [4] LC_NUMERIC=C
## [5] LC_TIME=English_United States.1252
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] fgsea_1.14.0    forcats_0.5.1   stringr_1.4.0   dplyr_1.0.3
##  [5] purrr_0.3.4     readr_1.4.0     tidyr_1.2.0     tibble_3.1.4
##  [9] ggplot2_3.3.3   tidyverse_1.3.0
##
## loaded via a namespace (and not attached):
##  [1] Rcpp_1.0.7          lubridate_1.7.9.2   lattice_0.20-41
##  [4] snow_0.4-3          assertthat_0.2.1    digest_0.6.27
##  [7] utf8_1.1.4          R6_2.5.0            cellranger_1.1.0
## [10] backports_1.2.1     reprex_1.0.0        evaluate_0.14
## [13] httr_1.4.2          pillar_1.6.2        rlang_0.4.10
## [16] readxl_1.3.1        rstudioapi_0.13     data.table_1.13.6
## [19] Matrix_1.3-2        rmarkdown_2.14      BiocParallel_1.22.0
## [22] munsell_0.5.0       broom_0.7.4         compiler_4.0.5
## [25] modelr_0.1.8        xfun_0.31           pkgconfig_2.0.3
## [28] htmltools_0.5.2     tidyselect_1.1.0    gridExtra_2.3
## [31] fansi_0.4.2         crayon_1.4.0        dbplyr_2.0.0
## [34] withr_2.4.1         grid_4.0.5          jsonlite_1.7.2
## [37] gtable_0.3.0        lifecycle_0.2.0     DBI_1.1.1
## [40] magrittr_2.0.1      scales_1.1.1        cli_2.3.0
## [43] stringi_1.5.3       fs_1.5.0            xml2_1.3.2
## [46] ellipsis_0.3.2      generics_0.1.2      vctrs_0.3.8
## [49] fastmatch_1.1-0     RColorBrewer_1.1-2  tools_4.0.5
## [52] glue_1.4.2          hms_1.0.0           parallel_4.0.5
## [55] fastmap_1.1.0       yaml_2.2.1          colorspace_2.0-0
## [58] rvest_0.3.6         knitr_1.31          haven_2.3.1
```